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by

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Summary of The Tandem Energy Focusing Explosive Warhead Technologies

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Abstract: In this paper, on the basis of a great amount of the analysis of the tandem energy focusing explosive warhead in our country and other countries, we summarize the design demand of the tandem warhead, the delayed ignition controlling technique between the explosives, the isolating explosion protection technique and the detonator technique.

Key Words: Explosives, Design, Tandem Explosive Warhead

1. Foreword

The tandem explosive warhead is the research project that the warhead designer pays attention to. As early as in the beginning of the 70's, the US began to develop this kind of structure. The goal of developing this kind of structure at that time is to counter the homogeneous target that constantly became thicker and the newly appeared composite target. In recent years, with the incessant competition and advancement of the fighting vehicles armor and the anti-tank explosive, more and more armors that employ advanced techniques emerged, especially the armors that are made of the nonmetallic materials such as ceramic, glass, or even the high energy explosive (active armor), etc. thus the penetration depth of the ordinary armor piercing bullet greatly decreased (the lose of the penetration depth is about 50% ~ 90%). The using of suitable designed tandem energy focusing explosive warhead to destroy the active armor is considered to be the most promising application of the tandem explosive warhead. It is definitely promoting the advancement of the tandem explosive warhead technology.

The tandem warhead has the characteristics of small caliber, big

power, and suitable for the anti active armor, etc. It can be used in the armored force weapon, all kinds of missiles and bombs, and is a kind of anti-tank weapon warhead that has a very bright developing future. In order to effectively counter the tank threats that would probably appear in the 90's, The Europe Missile Dynamic Corporation decided the design project of the third generation anti-tank missile, the tandem explosive warhead is a part of this project, especially for the Hota-2A new model anti-tank missile, this kind of missile began to use the tandem hollow explosive warhead to penetrate the increasing resistant armor. The missile department of the US army has signed a 15.2 million dollar contract with the Rockwell Missile System. They will cooperative to develop the tandem explosive warhead for the Hellfire missile. This kind of missile can penetrate the new model armor structure used in the T-80, T-72 and T-62 main fighting tank of the Soviet Union. The Dragon III (M47) missile of the US also employed the tandem explosive warhead and cooperated with the laser near explosion detonator, the armor penetrating depth can be 800 ~ 1000 mm. France developed the Dart 120 rocket projectile and anti-tank weapon, the armor penetrating power can reach 850 ~ 900 mm, the warhead of this kind of weapon is also the tandem mode and employs the optical near explosion detonator.

After hard working, the researchers of our country basically solved the key technical problem of designing the tandem explosive warhead and finished the preliminary prototype design of a certain tandem explosive warhead. This warhead can not only penetrate the heavy three layers spaced target of the North Atlantic Treaty Organization (NATO) in the armor piercing and simulated armor piercing, but also can reliably penetrate the heavy three layers spaced target of the NATO which has no reacting armor.

2. The design requirement of the tandem explosive warhead

In order to avoid that the explosion of the front explosive (later

in this paper also called the sub explosive or the secondary explosive) affects the rear explosive(later in this paper also called the main explosive or the primary explosive), there needs a explosion isolating device to protect the main explosive. It is usually to set up a partition between these two stages explosives.

There should be a reasonable delay time between the ignition of the main and the sub explosive

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to avoid interfering with each other and give full play to each one's function. The best delay time should be changed with respect to the change of the target's characteristic (homogeneous armor, and active armor) and the warhead's incident angle, etc.

The explosive cover of the tandem explosive warhead is designed following the old routine, but the design of the front explosive should be different according to the demand of the application. We take the reacting armor as an example, when we need that the front explosive ignite the reacting armor, the explosive cover is designed following the common demand; if we need that the front explosive only penetrates, does not ignite the reacting armor, it can be the energy focusing explosive or the self destructing fragment explosive. When we employ the energy focusing explosive, the diameter of the explosive cover is 25% ~ 70 % of the diameter of the main explosive, the ratio of the height of the cover to the diameter of the cover is in the range of 0.5 ~ 1.5, the thickness of the cover is 1% ~ 5% of its diameter. The material used in the cover could be aluminum alloy or magnesium alloy. When we employ the self destructing fragment explosive, the explosive cover can use the large cone angle structure or the mero-sphere structure. If the large cone angle structure cover is employed, the cone angle should be in the range of 140 ~ 170 degree, the thickness should be 1% ~ 2% of the diameter of the front explosive. If the mero-sphere structure is employed, the radio of the cover's height to its diameter should be about 0.05 ~ 0.15, its

thickness is about 1% ~ 2% of the diameter of the explosive.

In a word, when we design the tandem explosive warhead, the most important design demands are:

(1) Two fluxes should hit the target plane on the points that are very close.

(2) The motion of the pellet in the external trajectory should affect little about the flux impact point.

(3) The target characteristic (for example the armor design) is the main consideration to decide the explosion height near the target plane.

(4) We must carefully set up the delay time between the two ignition times of the two explosive, we must consider the explosion height and the possible danger that the two fluxes might collide.

(5) In the ignition period, the first stage explosive should not cause damage to the second stage explosive or too large displacement.

(6) The interaction between the first flux and the target should affect little to the main explosive.

3. The delay ignition controlling technique between the two stages explosive

In the tandem explosive, the delay time of the two stages explosive is very important. If it can not be controlled well, it will affect the valid length of the continuous flux and the acting effect of each intermittent flux. The delay of ignition time of the tandem explosives is decided according to the different usage. For example, to counter the homogeneous target, it is necessary that before the head of the second jet stream touch the head of the pellet, the first jet stream must have finished its penetrating acting, to counter the reacting armor, it is necessary that before the second jet stream touches the reacting armor,

the first jet stream must have finished its detonation to the reacting armor.

The major techniques of controlling the delay ignition of the two stages explosive include:

3.1 Delay the ignition using the air gap

As shown in the figure 1, this design scheme is raised by the Lawrence Livermore Research Center of the US. After the first explosive 14 is ignited by the detonator 18, while the flux passes the center tube 34, the transmitting plane 26 is accelerated by the first stage explosive, and hits the surface of the second stage explosive 16 violently with a certain speed and ignites it. The delay time between the two stages explosive is determined by the air

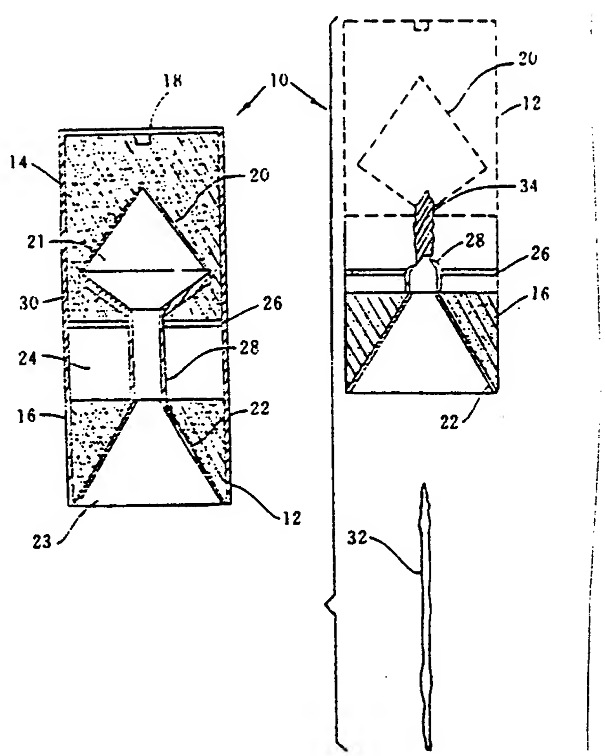
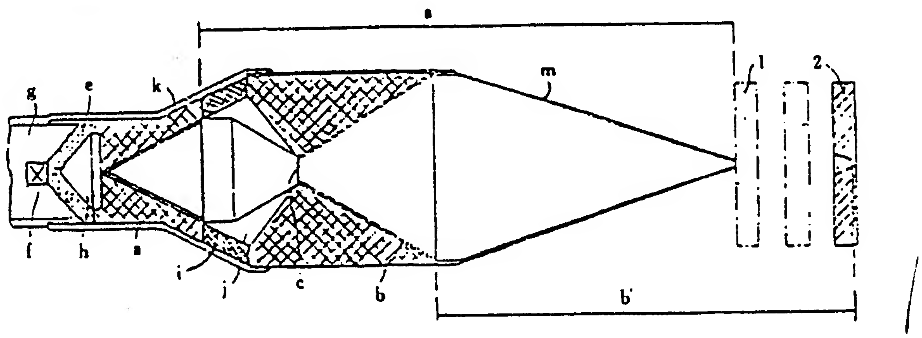


Figure 1. Delay the ignition using the air gap

24 between them. The typical delay time is about 30 ~ 50 .

3.2 The delay time by the delaying explosive

Figure 2 is the design scheme in the patent of the Federal Republic of Germany. After the first stage explosive is ignited, the second stage explosive can be ignited only through the delaying explosive 2. The similar design scheme is provided by the SERAT Corporation of France, only change is that the delaying explosive is replaced by the igniting fuse with a spiral form. The delay time is proportion to the length of the igniting fuse.



a. the first stage explosive i. the delaying explosive b. the second stage explosive

Figure 2. The delaying explosive controls the ignition of the second stage explosive

3.3 The electronic circuit controlled two stages explosion

The strong point of using the electronic circuit to control the ignitions is that this method can achieve very high precision timing, and can easily adjust the delay time.

For the electronic delaying circuit of the tandem explosive, attention should be paid to the four important design factors. The first is the explosion impact wave of the warhead, the second is the explosion gas cloud of the warhead, the third is the magnetoelectric pulse caused by

the warhead explosion, the forth is the magnetoelectric pulse caused by the slapper/sparkgap. They are all the factors that could cause the malfunction of the electronic circuit. They can cause that the warhead dud or igniting the main explosive too early.

A British patent shows another design scheme (figure 3), at first, this ignition circuit transmits the energy that is stored in the capacitor to the first pyrophoric capacitor through the transformer, then is delayed by the RC delaying circuit to ignite the second detonator. The whole module include: a device to store energy; a device that can couple a part of the energy to the first explosive detonator and ignite it; a device that can sense this energy coupling; a device that can response to this sensing and after a certain delay transmit the remaining energy to the second explosive and ignite it. The energy also can flow into the igniting circuit through the switch. The strong point of this patent is that it can reduce the damage and interference due to the impact wave.

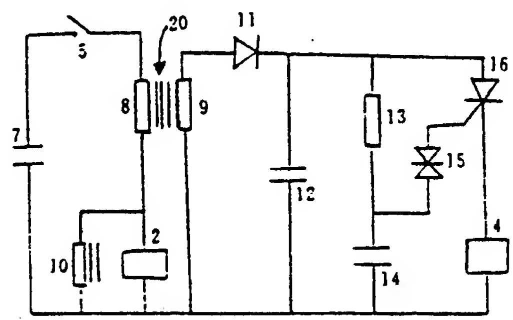


Figure 3. Igniting circuit

3.4 Ignition delay by the thermal insulation disk displacement

The figure 4 shows a design scheme provided by the patent of the US, its characteristic is that it uses the time that the thermal insulation disk moves from the initial position to the pre-determined position to achieve the time delaying. When the first explosive is ignited, the thermal insulation disk moves towards the rear of the warhead, then it hits the switch, the switch closes the circuit and enables the igniting

detonator of the second explosive. The time precision obtained by this method is relatively high.

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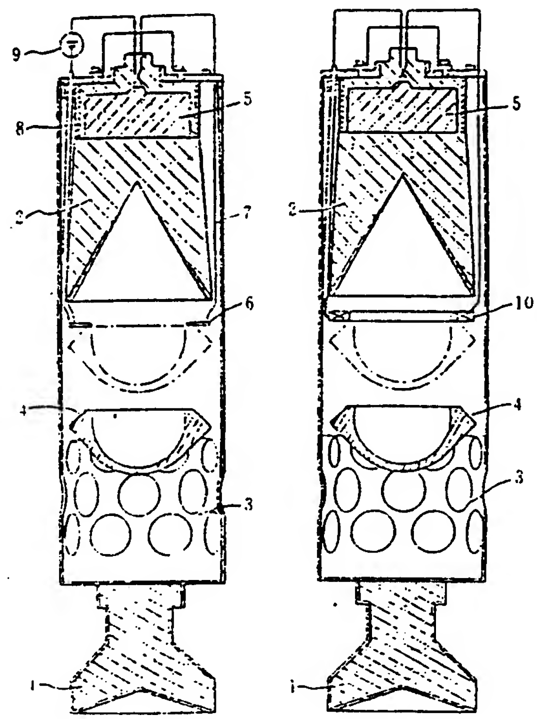

Figure 4. Using the thermal insulation disk to control the ignition of the second explosive

1. the first stage explosive 2. the second stage explosive 3. cover tube 4. thermal insulation disk

5. igniting system 6. switch 7. & 8. Electric wire 9. power supply

4. The explosion isolating device

Usually there are three methods to protect the main explosive so that it isn't affected by the explosion impact of the sub explosive.

(1). Using the mass of the relatively heavy metal block to isolate the main and the sub explosives. The metal block has relatively large inertia, so when the sub explosive is exploding, the inertia of the metal

block won't be accelerated to move backward and hit the main explosive. But the relatively heavy metal isolating block will reduce 20% of the penetrating effect of the main explosive. Although the metal isolating block protects the main explosive effectively, its mass increases the warhead mass, so it reduces the firing range and the destructive power.

(2) Using the existing components in the missile as the explosion isolating device. This method is feasible by the availability of those components in the missile; could those components stand the explosion impact of the sub explosive and if they can relocate themselves between the main and the sub explosives after being impacted.

(3) Using the air gap that is big enough to isolate and protect. The air gap can reduce the impact wave of the sub explosive before it affects the main explosive. But this method is difficult to be applied to the existing weapons. Usually it needs an extended part in the missile for it to gain extra space.

Larry, C. Mixon, etc. made a low cost and effective light weight fiber/epoxy resin explosion isolating block for the tandem explosive warhead (figure 5). This kind of composite material has very high strength and density, so it reduces the isolating block's weight greatly. At the same time, they also optimized the geometry design of the isolating block, so the weight of this composite material isolating block reduced 70% compared with the weight of the metal isolating block.

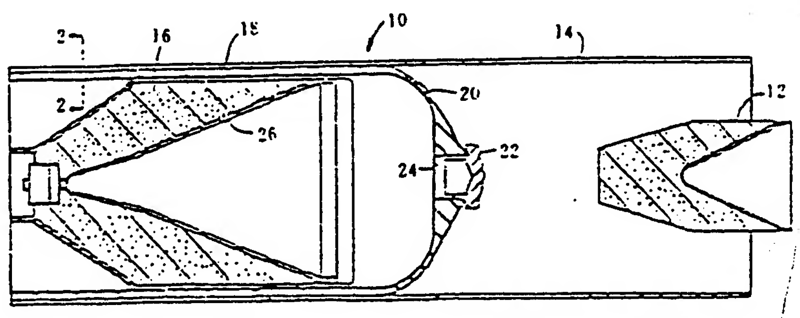

Figure 5. The composite material explosion isolating block locating between the stages explosive

In figure 5, the shell 18 of the explosion isolating block and the arc part 20 of the explosion isolating block form the whole explosion isolating block, there exists a hole 24 at the center axial position. After the secondary explosive12 explodes, the explosion impact wave and the explosion products rip open the shell 14, at the same time the weak link between 14 and the root of the 20 is damaged, so the explosion impact wave and the explosion products release through the rear and radial direction of the 20, thus the main explosive is protected. When the 16 explodes, the impact wave bumps the aluminum made cork 22, the flux formed by the explosive cover 26 shoots the target through the hole 24.

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As shown in figure 6, the safeguard device 4 between the two stages explosive is used to protect the second stage explosive, ensures that there will form stable flux after the explosive cover collapses under pressure. There is no limitation for the shape of this kind of explosion isolating plane protection device, it can be circular cone shape, sphere shape or basket handle shape, the thickness could be equal thickness, or varying thickness, it could be solid or have hole. The material of this isolating plane could be steel or other kinds of metal materials, also could be reinforced plastics.

The Israel Military Industry Corporation invented another kind of explosion isolating device (figure 7). When the sub explosive in the front ignites with a pre-determined way, the backward inflating gas produced by the explosion produces the impact wave, this impact wave puts pressure on the cone shaped bottom 18 of the connector, thus the connector part cracks, the inflating firing gas turns to the side direction and flows out along the oblique plane of the cone shaped protection device 16. The explosion result is that the whole warhead is broken up into two parts

and bursts out, but the protection device 16 and the missile main body that includes the rear main explosive engine are still undamaged, also keep the original trajectory. The protection device 16 avoids the missile's main body being damaged by the broken reacting armor and the inflating firing gas produced by the explosion of the secondary explosive11.

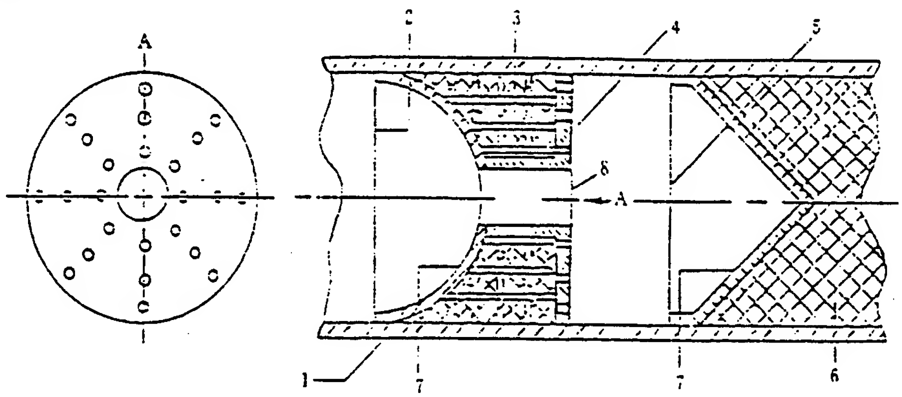

Figure 6. The longitudinal cross section of the tandem hollow explosive warhead

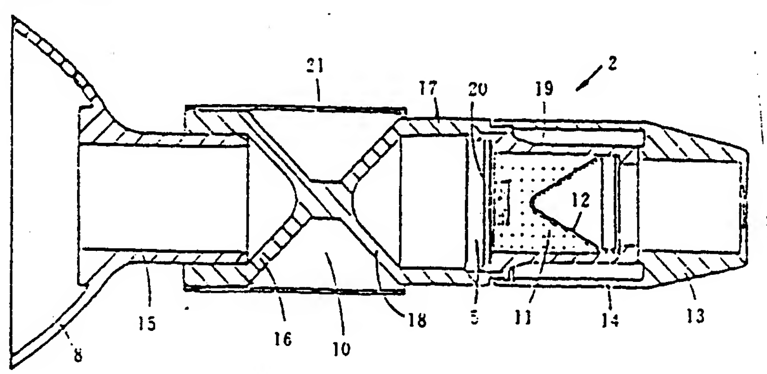

Figure 7. The axial cross section through the head of the pellet

5. The detonator technology of the tandem explosive warhead in the foreign countries

In recent years, the US, British, France, Germany, Sweden etc. issued many patents and research reports about the tandem explosive warhead one after another, but those reports relate to the double detonation controlling technologies are not available. It is thus evident that this kind of technologies are highly confidential. The

development survey of the anti-tank tandem explosive warhead detonator in foreign countries is shown in table 1.

The Hota-2A missile jointly developed by France and Germany is equipped with the tandem explosive warhead and the active laser near explosion detonator. The small hollow explosive that is called

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Table 1. The development survey of the anti-tank tandem explosive warhead detonator in foreign countries

No.	Country	Name	Warhead Structure	detonator
1	US	TOWA-2A	tandem explosive warhead	trigger near explosion
2	France, Germany	HOTA-2A	tandem explosive warhead	laser
3	France	MILAN-2A	tandem explosive warhead	solid laser near explosion
4	Europe	ATGW-LR, Long Range	tandem explosive warhead	forward looking laser near explosion
5	Europe	ATGW-MR, Intermediate Range	tandem explosive warhead	CO2 laser ranging
6	Europe	ATGW-MP	tandem explosive warhead	laser

7	US	Dragon III (M47)	tandem explosive warhead	laser diode near explosion
8	US	Hellfire AGM-114A	tandem explosive warhead	trigger near explosion
9	France	Short range anti-tank missile ACCP	tandem multiple stages explosive warhead	trigger
10	Brazil	MAC-MP optical fiber guidance anti-tank missile	tandem explosive warhead	

sub explosive is placed before the hollow explosive. When the internal laser distance meter measures the precise distance between the missile and the target, it ignite the explosive. Before the main explosive explodes, it will breaks the reacting armor. The Milan-2A missile of France contains explosion height stick, the front explosive stores in the stick and equipped with the solid laser near explosion detonator. The Dragon III (M47) missile of the US also has explosion height stick, the diameter of this stick is 40mm, the first stage explosive is in the stick and equipped with the laser diode near explosion detonator.

It is reported by the foreign references and documents that, the anti-tank armor piercing missile's tandem explosive warhead tends to be equipped with the laser near explosion detonator and the trigger detonator. But these detonators are still in their development stage. In

all kinds of near sensing schemes, the laser ranging can have the best precision, it is because the laser ranging is the earliest and the most mature technologies applied in the military. The target distance is the primary factor that affects the percentage of hits of the weapon's first strike. The most outstanding point of the laser ranging is its high ranging precision, and this precision is not related to the range of fire. Moreover, the whole device is small, the distance can be shown using digital, so it is suitable for the digital signal processing. Being compared with the microwave ranging, the laser ranging has narrow wave beam, high angle resolving power, strong anti-interference capacity, and is small and light weight.

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[2] Norman Williams, Tandem Warhead, GB 2221521A, 1989

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〔2〕 Norman Williams, Tandem Warhead, GB 2221521A, 1989